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Harmonic Impedances and Resonances in Oil and Gas Field Power Systems with Wind Energy Integration

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ABSTRACT

The causes of harmonic resonances in oil and gas production field are presented. The presence of harmonic impedance at point of common coupling (PCC) resulted in the generation of harmonic currents and voltages emanated from nonlinear loads, which has adverse impact on the systems performance. These drawbacks have been assessed and recommendations made for oil and gas field power systems network, with simulation tests on the new remote terminal platforms incorporating Wind energy in different cases such as the effect of Static Var Compensator (SVC) with harmonic voltages and currents injection, power factor correction (capacitor bank) with uprising harmonic resonances. Motor starting and motor on standstill where non—distorting linear load are under operation that account for forty per cent facilities in oil and gas production fields, have been simulated, the analysis is limited to one scenario oil field.

Keywords: Harmonic Resonances; Power Systems; Wind Energy

1. INTRODUCTION

The onshore and offshore oil and gas industry is far growing toward deeper sea and well for about few years now. Since the processes are growing with high complexity of climate change with electrical energy demanding. It is therefore imperative to put in place clean energy system. Proper harmonic analysis in oil and gas platform tops power quality and covers reasonable amount of safety standards for operating personnel and provides extremely high reliability. An advanced and flexible oil platform network with terminal back-to-back HVDC-VSC incorporating wind energy has been developed; it has the capability of feeding more than one production platforms with cost saving and lower energy losses. This topology is capable of stabilizing supply network and permit synchronous interconnected platforms, also the control of load flow fluctuations is achievable. An innovative technical power electronics converter concept allows energy transportation from remote offshore platforms to onshore platforms. High- power converters have found widespread applications in oil and gas industry. They can be used for pipeline pumps, cooling fans, drilling machines, oil rig water injection pumps, reactive power compensation, offshore grid integration of renewable energy sources and motor-drives operation. Motor to be

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started is assumed to be a large induction motor constituting approximately 10% of the total load on the platform. These motors have to run through the whole speed range from standstill to normal slip. Adjustable speed drives load may approximately constitute 40-50% of the total load on the platform. These loads may be rectifier-s powering DC motors or speed synchronous motors, which mainly consists of current source inverters (CSI) or voltage source converter (VSC). These converters bring forward strong tools for harmonic analysis, since they inject harmonic contents into the power systems network. The motor may be directly or by cable impedance connected to the grid at the point of common coupling (PCC). The power factor correction and SVC are directly connected to the network at the PCC. The single line diagram of oil platform with integration of wind farm is shown in Fig. 1.

2. ENERGY SOURCES ALTERNATIVE

A. Gas Turbines

The use of diesel generator as main energy supply to oil platform is age gone. At that time the platform is made of little equipment, but as the equipment increases, tight weight and space constraints crop up. This resulted in the deployment of gas turbine which has low energy conversion efficiencies particularly when operated at less than full capacity as is often the case. The turbine exhaust heat recovery systems and the utilizing dry low emission (DLE) combustion technology makes it complicated. As such CO_2 and Nitrogen Oxide emission occurs, a gas corrosive to both environment and health.

B. Wind Farms

As the world demand for oil and gas grows, oil production also increases as consequent demanding more diesel and gas for constant energy supply. This situation becomes worrisome, and then search for alternative means of energy supply began, this open way for wind energy source research. The new terminal oil and gas field is felt mainly with wind energy. The HVDC-VSC is utilized to transport energy to the platform. The system is environmentally friendly with no trace of hazardous emission at present. Therefore, it is evident that the overcoming energy source solution for onshore and offshore platforms is near from this view point.

Wind energies are based on constant speed with pitch control turbine. It is worth noting here that, the induction generator used in wind energy generation is embedded with overall field circuit, because of its attribute of absorbing constant loads, variable loads and natural protection against short circuit. The average power in the wind energy P_w is obtained by

$$P_w = \frac{1}{2}\rho A V^2 \tag{1}$$

The net effect of all losses is integrated into a parameter known as power coefficient C_p. The extractable power P_{ex} is obtained taking into account upstream velocity V_1

Therefore, $P_{ex}$is given as:

$$P_{ex} = \frac{1}{2}\rho A V^3{}_1 \tag{2}$$

the efficiency of the turbine rotor is:

$$C_p = \frac{P_{ex}}{P_w} \tag{3}$$

3. HARMONIC IMPEDANCE SCAN

A scenario where a nonlinear load draw distortion current from the energy source, this current goes through all impedances which are between the load and power supply. Consequently, causing voltage distortion, whose magnitude depends on the system impedances and the harmonic currents at harmonic frequency. The harmonic voltage and current distortion could be reduced by increasing the impedance of the power systems. The combination of thyristor-controlled reactor (TCR) with the capacitive reactance gives the Static VAR compensator (SVC) equivalent impedance at fundamental frequency given as:

$$S_{SVC} = \frac{\pi X_C X_L}{X_C(2\pi - 2\pi + \sin 2\alpha) - \pi X_L} \tag{4}$$

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The reactive power injected by the SVC is obtained as

$$q = \frac{V^2}{Z_{SVC}} \quad (5)$$

The dips voltage in the point of common coupling PCCI is given as

$$V_{dip} = \frac{Z_{TOTAL}}{ZTI + Z_{TOTAL}} E_{windenergy} \quad (6)$$

The harmonic current absorbed by SVCI and capacitor bank I are obtained as

$$I_{SVCI} = \left(\frac{Z_{TOTAL}}{Z_{SVCI} + Z_{TOTAL}}\right) I_{h1} \quad (7)$$

$$I_{CI} = \left(\frac{Z_{TOTAL}}{Z_{CI} + Z_{TOTAL}}\right) I_{h1} \quad (8)$$

Thevenin's theorem can be used to transform the network of induction motor into an equivalent voltage source VTH in series with equivalent impedance RTH + JXTH Therefore, the impedance of the induction motor could be obtained as

$$Z_{TH} = \frac{jX_M(R_1 + jX1)\left(\frac{R_2}{S} + jX_2\right)}{R_1 + j(R_1 + X_M)\left(\frac{R_2}{S} + jX_2\right)} \quad (9)$$

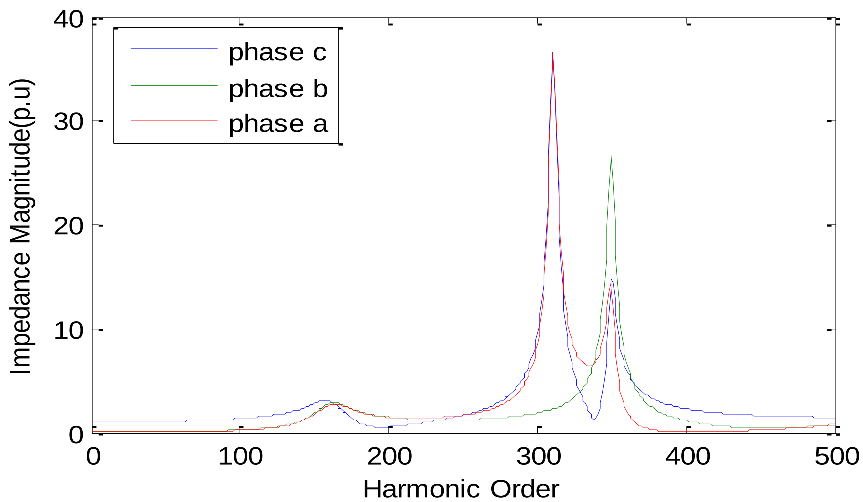

Fig. 1: Input Current with 3th Harmonics Injection

4. EFFECT OF COMPENSATOR BANKS

A major concern in the use of capacitor bank is the uprising of harmonic resonance in the power systems. Though this scenario will result in lowering harmonic voltage and current than would have been without capacitor bank. The parallel resonance observed in Fig. 1, occurs as a result of introducing capacitors bank in the systems. This injected harmonic resonance of 5th and 15 harmonics into the network at the fundamental frequency. The harmonic impedance presented in Fig. 2 shows two scenarios system configuration, first a system without capacitor bank and latter a system with capacitor bank. A clear indication that capacitor bank reduces harmonic voltage and current are show in harmonic spectrum Fig. 3.

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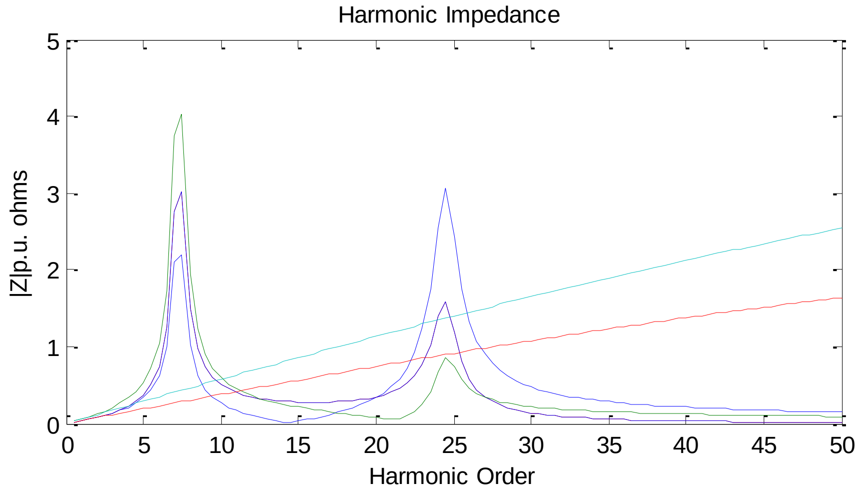

Fig. 2: Harmonic Resonance Impedance with Capacitor Bank

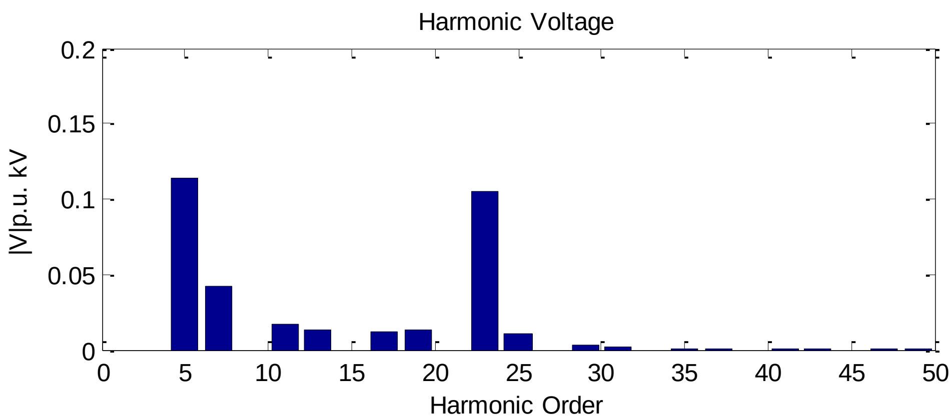

Fig. 3: Harmonic Voltage Spectrum of PCC1

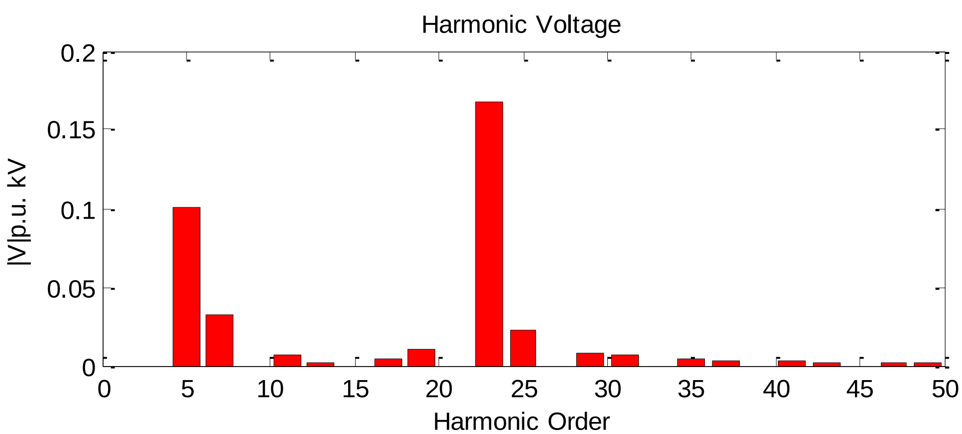

Fig. 4: Harmonic Voltage Spectrum of PCC2

5. CONCLUSIONS

Harmonic cases of typical oil and gas platform have been investigated. The impact of power factor correction (capacitor bank) was investigated using harmonic impedance at the PCC, this produces harmonic resonance with voltage excitation imbalances due to 5th and 15th harmonics. The use of SVC in the power systems platform reduces harmonic resonance mitigation. The employment of power factor correction together with SVC has proved to be a flexible and strong tool for the solution of harmonic voltage and

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current reduction in the oil and gas platforms. This also, compliment that one controllable input, SVC is required for harmonic resonance issues.

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Conflicts of interests
The authors declare that there are no conflicts of interests.

Data and materials availability
All data associated with this study are present in the paper.

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